Potential for Reducing the Environmental Impact of Construction Materials

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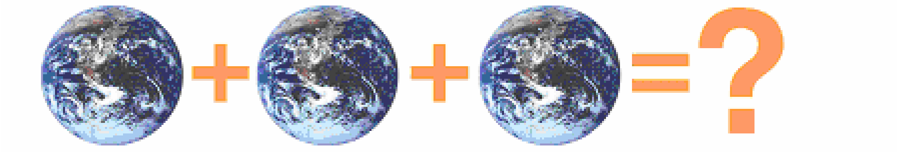
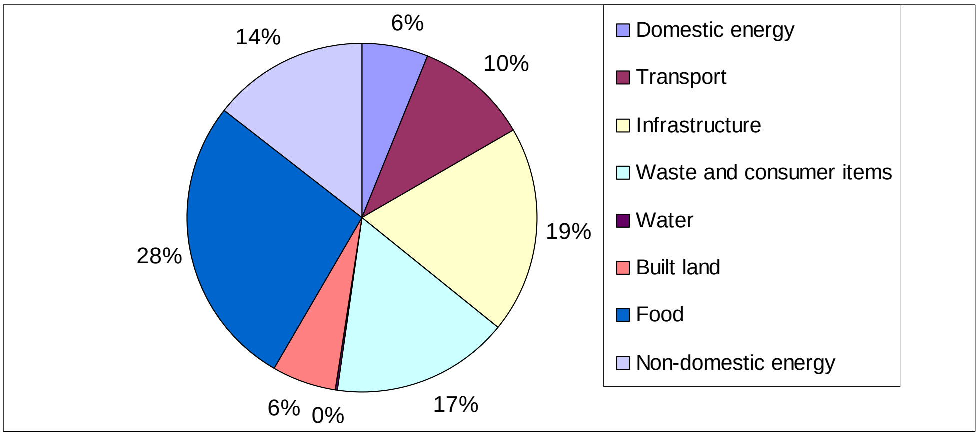
Introduction

According to the WWF Living Planet Report 2004, the eco-footprint of the average UK resident is 5.4ha. Our fair share of the earth's biocapacity is only 1.8ha. If everyone on the planet consumed as much as the average person in the UK we'd need three planets to support us.



Working with the Stockholm Environment Institute (SEI) and WWF, BioRegional carried out a study of the UK eco-footprint breakdown with the following results:



19% of the UK's eco-footprint is taken up by the embodied environmental impact of built infrastructure. This includes homes, offices, factories, roads, airports, railways, water treatment works, power stations, retail complexes etc. Every year materials are used to construct these facilities and it is the embodied environmental impacts of these materials – raw material extraction, processing, manufacture, haulage, packaging – that make up this section of our collective eco-footprint.

BioRegional are striving to find practical ways to reduce all sectors of the pie chart in order to meet the very difficult challenge of one planet living. They therefore felt that an overall study of the potential for reduced impact in this infrastructure category would be helpful. In particular, BioRegional are working on proposals for a 2,000 home mixed use development in the Thames Gateway. This project aims to demonstrate One Planet Living principles and also to achieve the "Z-squared" status of zero fossil energy and zero waste.

SEI have produced two reports from which this study has built on, Footprint North West and Taking Stock – an eco-footprint study of the South East. Both these documents report in detail on the resource flow and eco-footprint of that region and they make recommendations on how to reduce the eco-footprint by 75%. This report builds on the SEI work for the Construction sector and reports more specifically on how realistic those reductions are and how to achieve them.

A 75% reduction would mean reducing the eco-footprint of the construction industry from 61.5 million ha to 15.4 million ha. Each of the following sections looks at an aspect of the construction industry and suggests a "potential impact reduction" (PIR). The report ends by bringing together all the PIR's to make a total suggested impact reduction that is believed to be realistic and achievable.

Current Material Consumption

The following pie charts 1-3 show breakdowns of materials used in the construction industry, measured in tonnes but represented here as a percentage. Pie charts 4-6 show these materials represented as environmental impact – either embodied CO2 or eco-footprint. Data sources do vary in the quantities reported and their corresponding environmental impacts. It is beyond the scope of this study to reconcile the variations between all the different data sources. Three sources are shown here and despite discrepancies, they all highlight the same key material groups that are used in greatest quantities and they all highlight which materials result in the most significant environmental impacts.

The three data sources are:

1. DTI Construction Statistics Annual 2004 supplemented by quantities data from the 1998 CIRIA Waste minimisation and recycling in construction – Design Manual. DTI resource flow data in chart 1 is converted into embodied CO2 in chart 4 using BRE data by Nigel Howard.
2. City Limits report by Best Foot Forward
3. Taking Stock by SEI

Resource flow

Quarry products including stone, crushed rock, aggregate and sand make up between 51% and 62% of the resource flow. Cement and concrete products such as ready mix and concrete blocks are the next largest group making up 20-40% of the resource flow. Bricks, metals, glass and timber products each make up between 1% and 8% depending which data source is used.

Environmental impact

It is difficult to find consensus between the three data sources without further research into definitions and breakdowns of the material categories. All three sources show high impacts from cement (14%, 18% and 40%) and ready made concrete (16% and 10%).

Other categories that are significant are quarry products (7%, 2% and 22%), metals (22% and 2%), glass (5% and 16%), timber products (5% and 17%), bricks and blocks (16% and 5%). Plastics are only reported in the DTI statistics but are significant in their embodied CO2 at 7%.

Potential reductions

For the purposes of this study and for quantifying potential impact reductions, the DTI figures are used. The DTI statistics report the widest range of material types and annual figures are available to show trends. The embodied CO2 data from BRE is more accessible (for free) than eco-footprint data for individual materials.

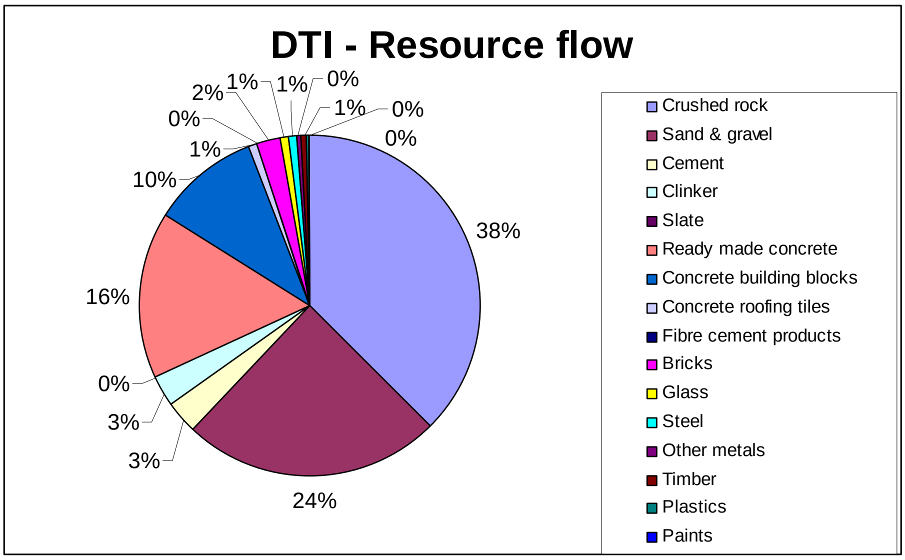


Chart 1

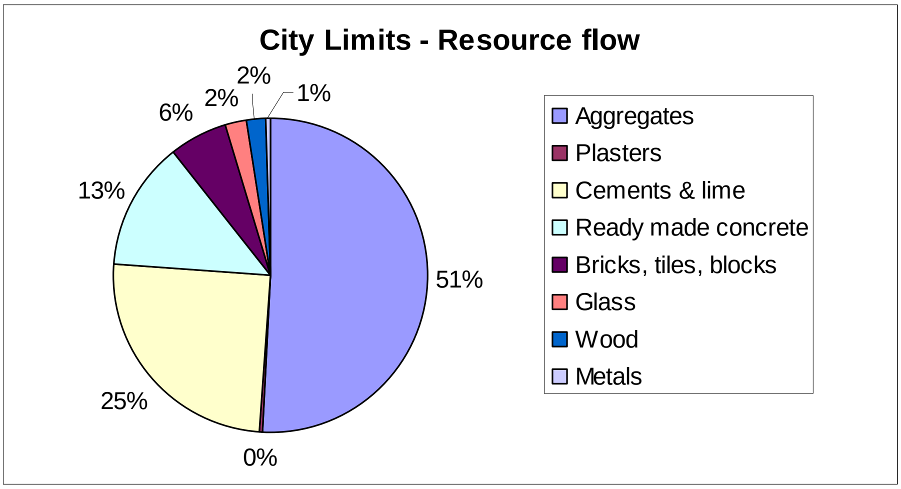


Chart 2

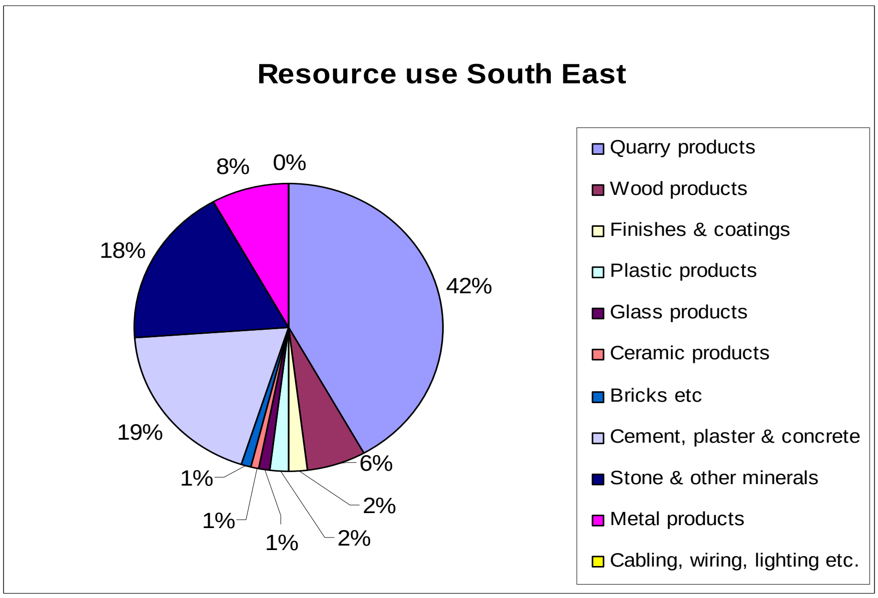


Chart 3

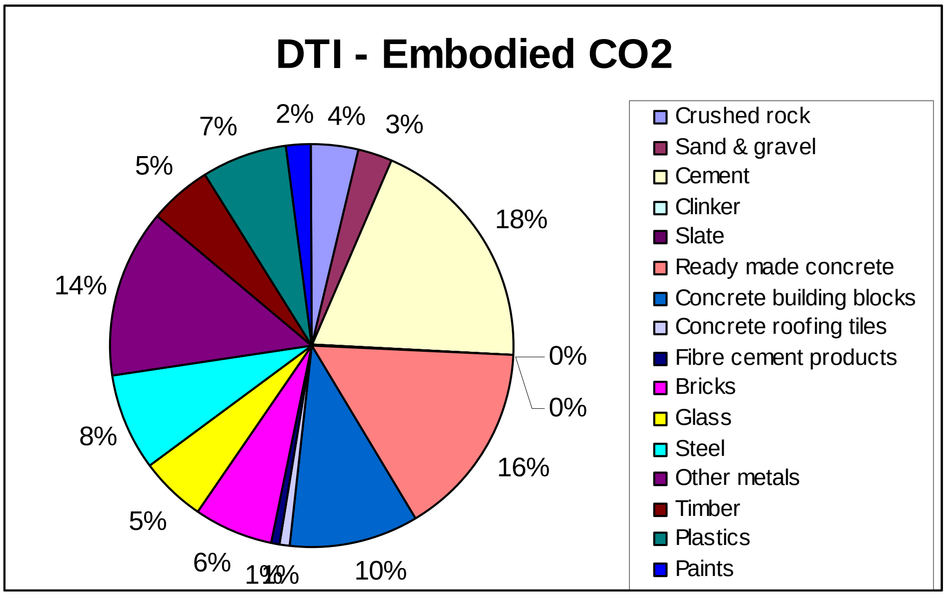


Chart 4

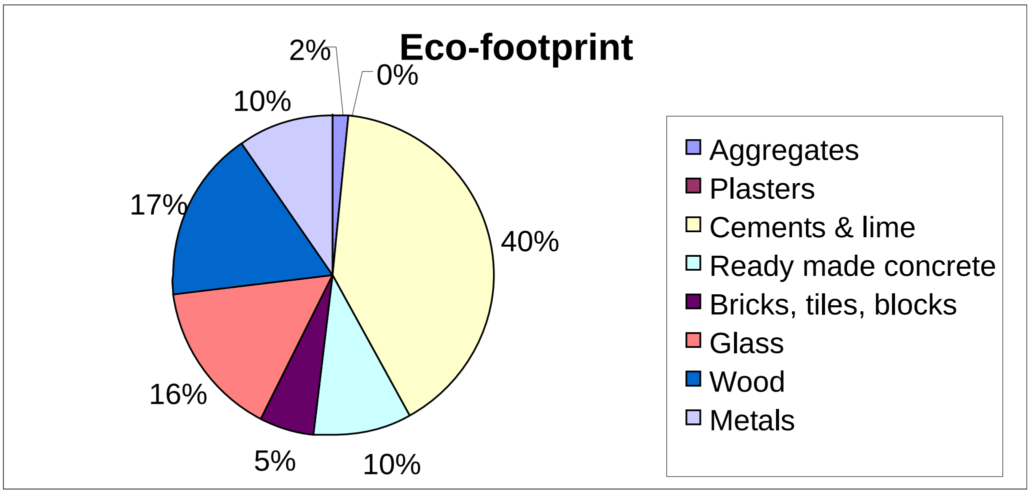


Chart 5

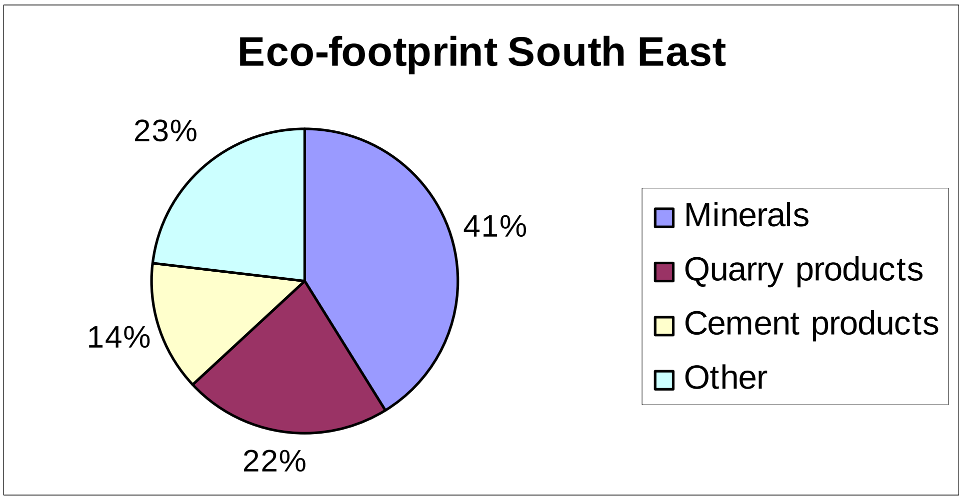


Chart 6

Infrastructure breakdown

The Taking Stock report says that there are 3 million dwellings in the South East region. New house building is targeting 28,000 per year in this region, representing a 1% per year expansion. The construction expenditure breakdown for the South East is reported as follows:

Housing	25%
Commercial	33%
Public services	11%
Industry	12%
Infrastructure	19%

The following table shows a detailed breakdown of expenditure taken from the DTI Construction Industry statistics for 2003 for the whole of the UK:

		Output £ million	%
New housing		15,184	16
Infrastructure		7,269	8
	Water	1,094	
	Sewerage	775	
	Electricity	425	
	Communications, gas & air	994	
	Railways	1,266	
	Harbours	382	
	Roads	2,333	
Non-residential		27,192	29
	Factories	2,325	
	Warehouses	1,361	
	Oil, steel & coal	103	
	Schools & universities	5,127	
	Health	2,319	
	Offices	6,184	
	Entertainment	3,254	
	Garages	370	
	Shops	4,183	
	Agriculture	249	
	Misc.	1,717	
Sub-total		49,645	
Repair & maintenance		42,876	46
	Housing	21,442	
	Non-residential	21,434	
Total output (£ million)		92,521	

Nearly half of the value of the contracts awarded within the industry is for repairs and maintenance to existing infrastructure. The other half is for new build and major refurbishment.

Expenditure on products and materials

According to WRAP, the construction industry spends around £22 billion each year on products and materials for new build (44% of industry contract values).

This study does not have data on the how much of the repairs and maintenance turnover is spent on materials but it is assumed that a higher proportion is spent on labour.

Environmental impact reductions

Expenditure generally bears some level of proportional relationship with environmental impact. Expensive building components often have more processing involved and so they usually have higher embodied impacts per tonne than cheaper raw materials. The above table can therefore be assumed to broadly indicate the relative embodied impacts associated with each category.

When considering long term regional strategies for impact reductions, these figures can be used to assess where it is worthwhile trying to reduce the need for new build.

For example, roads are the biggest expenditure under the infrastructure heading. By introducing efficiencies in delivery networks, green transport solutions and reducing the need to travel, then the demand for new roads could in the long term be reduced.

As another example, the largest impact area under the non-residential category is new offices, yet there are thousands of offices sitting vacant at present. Perhaps regional planning strategies could maximise the use of existing vacant offices before allowing the building of new ones.

According to the Urban Task Force report, there are some 4,500 hectares of land occupied by vacant commercial buildings. These provide the opportunity to either reduce the need for new commercial buildings, or they can be converted into 95,000 new residential dwellings with very low environmental impact investment.

In addition, there are around 753,000 vacant residential dwellings in the UK. This represents 3.9% of the housing stock. The Urban Task Force report suggests that some 150,000 of these could reasonably and economically be used to provide good quality desirable homes.

Refurbishing existing stock instead of building new will save more materials and haulage than any recycling or reclamation solutions. Where possible, this should be a preferred redevelopment approach.

As national policies to reduce demand for water and energy come into place, the long term need for construction of power stations and water treatment infrastructure is reduced. Fewer sub-stations, sewers and pump stations will be needed and this in turn reduces the need for repairs and maintenance.

These measures are all long term regional and national policy matters, subject to case by case conditions but if the overall need to build could be reduced by just 5% across all sectors, then the total PIR would be 3.1 million ha.

In addition, if buildings and infrastructure can be built with higher durability in mind, then materials used through repairs and maintenance could be reduced by, say, 2% and result in a PIR of 1.1 million ha.

Construction and Demolition Waste (C&DW)

According to the 4sight report, Rocks to Rubble, 72 million tonnes of C&DW is produced every year in the UK. This accounts for 17% of the total 420 million tonnes of waste. Of this, about one third (24 million) is brick and concrete waste.

According to WRAP, C&DW waste is higher at 90 million tonnes of which half is recycled within the construction industry.

13 million tonnes of this waste are unused materials that are over ordered or incorrectly ordered. The materials are thrown away as waste or recycled (ref. 4sight). This represents 3% of the industry's resource consumption. Contractors will always need to over order to some extent and mistakes will always occur in material procurement but if these mistakes could be reduced by just 10%, that would save 1.3Mt of material and 0.2 million ha of eco-footprint.

If 75% of the remainder of over ordered material could be reclaimed and used else where, then a further 8.8Mt of material would be saved representing an eco-footprint saving of 1.3 million hectares.

Improved manufacturing

The environmental impact of all building materials depends on the processes used to extract, process and manufacture them. Many companies are now under pressure to improve their environmental performance and to demonstrate that improvement. Increasing energy efficiency, reducing industrial waste, reducing any polluting emissions either to air or water, all such measures will increasingly save the company money in the long run and often improve their public image.

Large companies are signing up to the environmental accreditation scheme ISO14001. For example, Corus have implemented ISO14001 across 95% of their organisation and in order to demonstrate continuous environmental improvement they have set a range of targets to report against. Targets included:

- Reduce total energy consumption by 10% in the UK by 2010
- Reduce waste to landfill by 10% by 2002
- Increase the amount of steel packaging waste recycled by 20% by 2002
- Reduce potable water consumption by some 11% by 2000.
- Reduce secondary dust emissions from electric arc steelmaking operations by 10% by 1997.

Corus claim to have achieved all these targets.

Another example is Rockwool who use an energy intensive process to manufacture rock mineral fibre insulation materials. They claim that since 2000, they have reduced their CO2 emissions by 8% through energy efficiency measures.

If the manufacturers of all building products could improve their environmental performance across the board by an average 10%, then that would result in an eco-footprint saving of 5.0 million ha.

Improved energy generation

> "The CO_2 produced by electricity generation in the UK has been steadily falling as we decommission inefficient old coal fired power stations, use more of the new gas fired power stations, buy more from France's nuclear generation, and get increasing efficiency from the UK's nuclear generation.
>
> In the early and mid 1990's the government quoted figure was 0.72kg CO_2/kWh (ECON19). In late 1998 this was lowered to 0.52 (ECON19:1998) and in 2000 it was published as 0.46 (ECON19:2000)."
>
> Chris Twinn, Arup

Renewables in 2002 met only 2% of the UK electricity demand. If the electricity industry can meet the government targets of 10% renewables by 2010, and if that increase in renewables is replacing fossil fuels, not nuclear, then carbon emissions from electricity production will be reduced by 8.2%.

If similar improvements are occurring in other countries in the world where some of our building products are being manufactured, then the embodied CO_2 of these products is reducing.

Part of the embodied CO_2 of any building product is made up of the haulage and the associated burning of freight fossil fuels. Possible improvements on this score include the Australian example of introducing 10% biodiesel to all diesel fuel. Vehicle and shipping efficiencies may also be driven to improve as the cost of fossil fuels rise.

If improvements across the board in all these areas can match the 8.2% of the UK renewables obligation then the embodied impact of all construction materials actually reduces by that amount and saves an eco-footprint of 4.5 million ha.

Local sourcing

Haulage of construction materials within the UK accounts for some 20% of the embodied impact of construction. Experience on BedZED showed that by simply choosing the most local supplier for standard products, haulage of materials can be reduced significantly compared with national average haulage distances recorded by BRE. On BedZED the total embodied CO_2 of all construction materials was reduced by 2% through local sourcing. This was a simple, cost free measure and if replicated across the industry would save 1.1 million ha.

Increased recycled content

Increasing the recycled content of building materials achieves two things. It diverts waste from landfill, generating a market for materials that would otherwise cost money and land to dispose of. It also displaces the need for new materials.

The degree to which increasing recycled content actually reduces environmental impact is different for each product and for each source of recycled material. Ideally a life cycle analysis would be carried out on each product but this is too expensive for this particular study.

Recycled materials require reprocessing such as crushing, chipping or melting. All these processes require energy and result in waste and emissions. For there to be an environmental advantage, the impacts of the reprocessing need to be less than the impacts of using new.

Recycled steel is used extensively throughout the world and has just half the embodied energy of virgin raw material steel. BRE environmental profiling has shown that crushed concrete aggregate has an ecopoint impact of about half that of virgin aggregate. Crushed green glass sand has an ecopoint impact of about 5% of that of virgin sand. However, this study has not come across any data on the relative environmental impacts of chipped timber products or recycled plastic products.

WRAP and BRE are working extensively on assessing current standard practice in building products and their recycled content and potential improvements. There are numerous reports and case studies for particular materials on the WRAP website and there is a report specifically on building materials for the house building industry which says that 10% recycled content by value is achievable at no extra cost. It says that by using the recommended "best practice" indicators, this could increase to 20%.

"The potential exists to recover and re-use much more material, both from C&DW and from other waste streams. For example,

- Aggregates - WRAP estimates that a further 20 million tonnes a year of recycled and secondary materials could be used
- Glass – The UK generates up to 5.5 million tonnes of glass waste each year, of which we currently recycle less than 20%.
- Plastic – Of the 1.4 million tonnes used in construction each year, only 10% is recycled content.
- Wood – Over 9 million tonnes of timber-based products are used by the construction industry each year. Only one third of a million tonnes is recycled wood, of the 3-5 million tonnes of waste wood available."

House Building Quick Wins, WRAP

The following table uses resource flow data from the DTI Construction Industry statistics for a range of building material types. It converts those resource flows into embodied CO2 using BRE data by Nigel Howard. The table then suggests potential increases in recycled content using information from the WRAP House Building Quick Wins guide and from industry targets. The reduction in embodied CO2 for the use of that material is then calculated using a PIR factor. The PIR factor is an estimate of the potential impact reduction brought about by using that particular recyclate. For example, a PIR factor of 0.8 is used for cement where a proportion of cement is replaced by GGBS. It is estimated here that GGBS has an 80% reduction in environmental impact compared with cement.

PIR from increased recycled content	Resource flow ("000 tonnes)	Embodied CO2 ('000 tonnes)	Increased recycled content ('000 tonnes)	PIR factor for recycled content (%)	Embodied CO2 reduction ('000 tonnes)	% reduction
Crushed rock	126,568	2,772	20,000	0.55	241	3.6
Sand & gravel	82,539	1,808	5,500	0.75	90	1.4
Cement	11,072	13,504	1,107	0.80	1,080	16.3
Slate	78	1	~	~	0	0.0
Ready made concrete	53,494	10,862	10,700	0.80	1,738	26.2
Concrete blocks	34,644	7,256	3,464	0.90	653	9.8
Concrete roofing tiles	2,568	538	257	0.90	48	0.7
Fibre cement products	158	468	16	0.90	43	0.6
Bricks	7,409	4,408	370	0.95	209	3.2
Glass	3,349	3,786	~	~	0	0.0
Steel	2,500	5,333	~	~	0	0.0
Other metals	850	9,520	~	~	0	0.0
Timber	1,925	3,504	385	0.80	560	8.4
Plastics	550	4,934	275	0.80	1,973	29.7
Paints	410	1,353	~	~	0	0.0
		70,044			6,637	
					% reduction 9.5	

The total PIR from increased recycled content is estimated here at 9.6%. This overall reduction is based on the following:

1. 20 million tonnes a year of additional recycled and secondary aggregate materials as suggested by WRAP. (This exceeds the Mineral Planning Guidance target of an increase of 12 million tonnes by 2006.)
2. 5.5 million tonnes of crushed glass sand used instead of virgin sand. (This requires all recycled glass to be used for this purpose.)
3. 10% additional use of GGBS and PFA instead of cement as suggested by WRAP best practice advice. See p…
4. Ready made concrete, concrete blocks and concrete roofing tiles to increase GGBS, PFA or recycled aggregate content by 20%
5. Bricks to increase recycled clay content by 5%
6. Timber products to increase recycled chip or sawdust content by 20%
7. Plastic products to increase recycled content by 50%

These are ambitious targets to achieve them across the industry but the WRAP guide has declared these measures technically and practically possible. The cost implications are also covered in the WRAP report.

Reclaimed Building Materials

The re-use of waste building materials in their existing state without down-grading and reprocessing is the most environmental option for supplying construction projects (apart from not building at all). There is a massive resource of materials coming out of demolition sites or being dismantled from temporary works. The potential for using these materials, diverting them from landfill or reprocessing, and displacing the need for new materials is enormous.

The following table shows the maximum haulage distance it is worth moving a reclaimed material before the environmental advantage is lost.

Maximum transport distances for reclaimed materials to have environmental benefits over new	
Material	Distance (miles)
Tiles	100
Slate	300
Bricks	250
Aggregates	150
Timber	1000
Steel products	2500
Aluminium products	7500

BRE Green Guide to specification

BioRegional have done a considerable amount of work in this field both through the BedZED project and through their trading subsidiary, BioRegional Reclaimed. They are working in the market place with contractors, designers and Clients to establish supply chains for reclaimed steel, timber, bricks and blocks, tiles and paving solutions, doors, glass panels and stone. Reclaimed materials save up to 95% of their embodied impact, even compared with products that have a large recycled content.

Salvage is nothing new. There is a well developed market in high value architectural salvage items and there are hundreds of reclamation yards trading on a small scale for DIY, historic refurbishment and green minded self build projects.

The current barriers to growth in this area are logistical. Large volumes of low value materials need haulage and storage. The cost of extraction from demolition sites can sometimes be prohibitive and the new document, the Design for Deconstruction movement will hopefully address this in the future. The Demolition Protocol and the New Build Recovery Index provide tools for maximising the materials recovered and incorporated into new build.

The reclamation industry is not service orientated to the same extent as builders' merchants. It does not tend to supply large volume orders. Quality and price vary considerably. It is very difficult for medium to large building projects to secure any consistent supply of reclaimed building materials because the reclamation yards are not equipped to trade at that scale. Existing reclamation yards tap into just a tiny fraction (<0.1%) of the reusable materials coming out of demolition jobs.

As for the previous chapter on recycled content, the following table uses DTI resource flow data and embodied CO2 figures for a range of building materials. The table then suggests potential increases in the use of reclaimed building materials based on C&DW figures, data from Salvo and using the direct experience of BioRegional Reclaimed. The reduction in embodied CO2 for the use of those materials is then calculated using a PIR factor. As before, the PIR factor is an estimate of the potential impact reduction brought about by using that particular reclaimed material.

PIR from increased use of reclaimed materials	Resource flow (''000 tonnes)	Embodied CO2 ('000 tonnes)	Increased reclaimed use (''000 tonnes)	PIR factor for reclaimed materials (%)	Embodied CO2 reduction ('000 tonnes)	% reduction
Crushed rock	126,568	2,772	0		0	0.0
Sand & gravel	82,539	1,808	0		0	0.0
Cement	11,072	13,504	0		0	0.0
Slate	78	1	39	0.95	0	0.0
Ready made concrete	53,494	10,862	0		0	0.0
Concrete blocks	34,644	7,256	3,464	0.95	689	9.0
Concrete roofing tiles	2,568	538	0		0	0.0
Fibre cement products	158	468	0		0	0.0
Bricks	7,409	4,408	2,470	0.90	1,323	17.2
Glass	3,349	3,786	0		0	0.0
Steel	2,500	5,333	1,000	0.95	2,026	26.4
Other metals	850	9,520	255	0.95	2,713	35.3
Timber	1,925	3,504	642	0.80	935	12.2
Plastics	550	4,934	0		0	0.0
Paints	410	1,353	0		0	0.0
		70,044			7,687	
					% reduction 11.0	

The total PIR from increased use of reclaimed materials is estimated here at 11.0%. This overall reduction is based on the following:

1. Concrete blocks and paving to be 10% reclaimed
2. Slate to be 50% reclaimed
3. Bricks to be 33% reclaimed
4. 40% of all steel to be reclaimed
5. 30% of all metal products to be reclaimed
6. 33% of timber products to be reclaimed

These measures are ambitious but all technically feasible. At this scale they would also be economic. They do, however, require new extensive supply chains and changes from demolition to a dismantling approach.

Choice of materials

The BedZED Construction Materials Report showed how by choosing low impact materials and low impact components carefully, embodied impact can be reduced significantly. The following table indicates some environmental impact savings through choosing to use less concrete, less cement, less uPVC and more timber. This can be achieved not only by simple choice of materials but also by efficient design (eg. Prestressed concrete uses less concrete to do the same job), or prefabricated components can result in less wastage. These are “finger in the air” figures designed to give a realistic overall reduction similar to BedZED.

PIR from substituting high impact materials with low	Resource flow (''000 tonnes)	Embodied CO2 ('000 tonnes)	Change of use (+/- '000 tonnes)	Change in embodied CO2 (+/- '000 tonnes)
Crushed rock	126,568	2,772	0	0
Sand & gravel	82,539	1,808	0	0
Cement	11,072	13,504	-3,000	-3,659
Slate	78	1	0	0
Ready made concrete	53,494	10,862	-10,000	-2,031
Concrete blocks	34,644	7,256	-10,000	-2,094
Concrete roofing tiles	2,568	538	-700	-147
Fibre cement products	158	468	0	0
Bricks	7,409	4,408	0	0
Glass	3,349	3,786	0	0
Steel	2,500	5,333	-1,000	-2,133
Other metals	850	9,520	-200	-2,240
Timber	1,925	3,504	3,850	7,007
Plastics	550	4,934	-200	-1,794
Paints	410	1,353	0	0
		70,044		-7,091
				% reduction -10.1

A move away from concrete, metals and plastic and an increase in the use of timber products could bring about this reduced total impact but may also have a detrimental affect on long term durability. As repairs and maintenance make up almost half the construction industry budget and most likely a good proportion of the environmental burden, this approach would need to assessed on a case by case basis.

Aggregates

The construction industry accounts for over 90% of mineral consumption in the UK and, of this, one-third is used in road construction. Other uses include buildings, railways and manufacturing of cement, lime, plaster and a variety of other products such as glass and ceramics. (ref. 4sight)

Quarry products including stone, crushed rock, aggregate and sand make up between 51% and 62% of the resource flow of the construction industry. This amounts to some 240Mt of material. In the Taking Stock report, SEI state that quarry products account for 22% of the industry's total eco-footprint.

According to the Quarry Products Association, 18% of the UK's aggregate demand is met from recycled sources. The Minerals Planning Guidance (MPG 6) sets a target of 55Mt for use of recycled and secondary material by 2006 (ref. 4sight). This equates to ~23% or an additional 12Mt compared with current practice. In the House Building Quick Wins guide, WRAP estimate that an additional 20Mt of recycled and secondary material could be used in place of virgin material if best practice is adopted.

The 4sight report, Rocks to Rubble, states that 72 million tonnes of C&DW is produced every year in the UK. Of this, about one third (24 million) is brick and concrete waste that can be used for recycled fill or aggregate. Approximately 75% of this waste is recycled in some form. Eg. See Case study 1.

There are a wide range of applications for recycled or secondary materials in replacing the need for virgin aggregates. Applications for earth fill, road sub-base fill and Type II material have made use of recycled material and crushed concrete for some years. However, there are very few examples of recycled aggregate in concrete applications in the UK. Low strength concrete applications are technically suitable for recycled aggregate but until 2004 these applications were covered in BS5328 which restricted the designer to "natural" aggregates or blast furnace slag aggregates.

The new British standards may well have addressed this barrier and a supplementary paragraph will be added to this report in due course to report on the new standards. Recycled crushed concrete aggregate has however been used in a number of concrete applications in the UK such as the BRE's Environmental building, Wessex Water's headquarters (see Case Study 2 below) and in the Bexley Council case study 3 below.

Recycled crushed glass was used in place of virgin bedding sand on the BedZED project and is now used in common practice for bedding paving slabs. It is also possible to use recycled glass as a concrete additive as described in case study 4 below.

Secondary materials, which are wastes left over from industrial processes such as blast furnace slag, pulverised fuel ash (PFA) and incinerator bottom ash, can also be used as construction material. PFA, for example, is used in road construction and in several construction applications such as light weight aggregate manufacture, cement replacement, additive in concrete and brick manufacture. Incinerator bottom ash is used for fill, or as aggregate for asphalt and concrete building blocks. Ground granulated blast furnace slag (GGBS) is used in standard concrete mixes replacing up to 50% of the cement content. It is possible, however, to use an even higher GGBS content in certain circumstances (see case study 5 below).

Case study 1
The Pinden waste disposal site near Dartford in Kent looks like any other landfill site. The difference is, however, that some 80 per cent of the material which comes in through the gates leaves again after separation and processing to satisfy the growing demand for recycled materials. Only after every avenue for recycling has been exhausted does the company commit a residue of 5,000 tonnes a year to landfill.

Ref. QPA website

Case study 2 – Wessex Water HQ
The sustainable design of the Wessex Water HQ on the outskirts of Bath received a BREEAM rating of Excellent. The concrete in the building uses recycled concrete aggregate from railway sleepers. Additionally, 75% of the waste generated during construction was recycled.

Geoblock Grassway interlocking plastic blocks made from 100% recycled material were used for construction of a lay-by as an alternative to concrete.

Case Study 3 - Recycled concrete aggregate

Construction of a concrete access road to Hillview Cemetery, Welling

In 2001, Bexley Council needed to construct a new perimeter access road at Hillview Cemetery in Welling. The use of flexible materials was initially considered, but the under laying clay sub-grade would have made this uneconomical. The chosen solution was a reinforced concrete pavement. Recycled concrete aggregate was used as a sub-base material and as the coarse aggregate for the pavement quality concrete. The London Borough of Bexley have subsequently extended the use of recycled concrete aggregate throughout the borough in a range of applications. Key issues were to ensure that the recycled material contained minimal organic content. Crushed concrete provided for the coarse fraction (20mm – 5mm) of the mix but the fines (5mm and less) were replaced by primary materials.

Financial: Total cost saving compared to using primary materials of £500.

Technical data:
Material was pre-screened and crushed by Erith Group and then passed through a secondary screen for grading. Material was then mixed to concrete by J Clubb Ltd. The crushed concrete material is fit for use in non-structural concrete sub-base. The material is labelled as P300 (RA), being of a C30 strength, equivalent to BS 5348/8500, of a grade ST4 or GEN 3.

Tests are carried out in accordance with BS 812 to ensure grading of material compliant with BS 822. The aggregate is handled to the BSI Kite Mark scheme. Mix designs are developed by a process of trial mixing and cube crushing procedures to BS 1881. All mixes are regularly sampled and the slump, wet density and compressive strength of concrete produced is tested to BS1881. The mixing, dispatch and delivery of the finished products is carried out in accordance with BS 5328/8500 and in accordance with the BSI Kite Mark Scheme.

Specification: Recycled concrete aggregate is permitted for use in Type 1 according to the Specification for Highways Works, Clause 803.

Case study 4 - Crushed recycled glass in concrete

The WRAP-funded ConGlassCrete I Project has looked extensively at the use of crushed and ground glass in concrete products as a replacement for cement and/or aggregate. A total of 19 products with 98 mixes were manufactured in precast concrete factories and tested for compliance with British Standards. The main findings of the study were that all the test products were found to have equivalent test results as conventional products.

Detrimental chemical reactions seemed to take place only with high alkali cement and this reaction was reduced to almost zero by using PFA or GGBS at normal replacement levels for Portland cement.

Case study 5 – GGBS content increased to 75%

During the weekend of 17-19 July, 1992, Clugston Construction completed the casting of a massive reinforced concrete slab in the airship hangar at the Building Research Establishment, Cardington.

The 68.0m x 44.0m x 1.2m slab was completed in a continuous 3,600m3 pour over a 36 hour period. Over 600 truck mixer deliveries were required to discharge at approximately one load every 3 minutes in order to satisfy Clugston's placing rate of 100m3 per hour.

GGBS was specified in the concrete mix in order to reduce the heat generated within the concrete and reduce the risk of thermal cracking. A blend of 25% CEM I PC and 75% GGBS was used and the characteristic strength of the concrete was specified to be achieved at 56 days rather than the more normal 28 days.

The benefits of using high slag replacement CIII B Blastfurnace Cement (BC) to reduce the risk of early age thermal cracking were clearly illustrated.

Concretes containing GGBS exhibit continued strength gain beyond 28 days. When a structure is not to be loaded for some time after casting it is possible to take advantage of this fact by using lower cementitious contents. This will further reduce temperature rise while enabling strength criteria to be met at later ages.

On this project, in order to keep cementitious content to a minimum and thereby minimise temperature gradients, the 28 day strength criterion was relaxed to 56 days.

Timber products

Timber products make up somewhere between 5-17% of the eco-footprint of the construction industry. One of the most important environmental considerations with timber is to source it from a sustainably managed source. FSC or other accreditation schemes are not reflected in eco-footprint or embodied CO2 calculations but the provenance of new timber must be taken into account when considering environmental impact of this material.

Unprocessed timber products have much lower eco-footprints than chipboard, plywood or other such materials than include resins and bonding material.

Separation of timber waste on construction and demolition sites is fairly common practice and timber waste is sent for chipping and reprocessing fairly successfully. However, the ideal environmental solution is the re-use of timber products. Beams, studwork, floorboards and doors can all be re-used and reclaimed.

The case study below is just one example of a business supplying reclaimed timber to self build projects and individual historic refurbishment projects. There is still very little use of reclaimed timber in the large scale building contracts. It is in that sector that there is most room for environmental impact reduction.

BioRegional Reclaimed have been supplying studwork, floorboards and doors for various projects. The salvage industry offers a well developed market in reclaimed timber products but the potential for much higher throughout and re-use is not being realised. In the reclaimed chapter of this report, it is suggested that a third of the current demand for timber products could be met from reclaimed timber.

Case Study - Reclaiming Timber for Flooring and Joinery

Introduction
Elaine Barker established Timber Reclaimed in 1997 supplying reclaimed timber flooring and joinery.

Sourcing the Raw Material
Timber Reclaimed purchase beams from demolition contractors or timber trade dealers. The beams are then prepared for re-milling as floorboards and joinery such as skirting boards, staircases and doors. The most common forms of reclaimed timber are Pitch Pine, Douglas Fir, Yellow Pine and very occasionally Oak (the most expensive).

As far as size is concerned, the bigger the better, since larger beams reduce the amount of labour required to convert them. However, larger beams are less common these days. Timber beams are mostly salvaged from sites which are not demolished entirely by mechanical means. The larger the contractor, the more likely the operation will be entirely mechanised and the less likely there will be salvaged timber available for the reclamation industry. Developing relationships with contractors with the correct profile is therefore very important. The amount of suitable raw material has also decreased since the introduction of European legislation which effectively forbids the reuse of timber which has been treated with creosote except in very limited applications.

Timber Reclaimed pay an average of £6 per cubic foot for Pitch Pine (the Reclamation Timber Industry is defiantly imperial), up to £8.50 per cube for de-nailed beams and £13-17 per square yard for rough-sawn boards. They carry out de-nailing, rough-sawing, kilning and planing.

Demand for the Finished Product
Whilst it is possible to pick up old floorboards and doors from reclamation yards very cheaply, the finished reclaimed product is not a cheaper alternative to new timbers - this is a common misconception. It does, however, compare well with the higher quality hardwood flooring. Despite the cost implications there is a healthy demand from:

- the self build market
- the designer and architect market
- owners of Period Properties and
- the professional joinery market

Distribution
This is a significant cost and, except in the case of large orders, is passed on to customers at cost as a discrete item. This can be uncompetitive on smaller orders in locations that are not on a popular haulage routes. The size of the business means that Timber Reclaimed must rely on third party haulage companies.

Costs
Timber Reclaimed have assumed that reclaimed Pitch Pine is used throughout and that a cubic foot of reclaimed timber will produce 0.66 of a square yard of flooring – this allows for wastage of 0.55 of a square yard.

Raw material	
5,000 cubic ft @ £6 per cubic ft (includes transport to site)	£30,000
De-nailing	
1275 man hours at £7 per hour	£8,750
Rough-sawing	
£3 per cubic ft	£15,000
Kilning	
£1.50 per cubic ft	£7,500
Planing	
Assume that there is 2750 sq m and an average face width of a floorboard is 125mm and a cost for planing a linear metre is 75p	£16,500
Advertising	£1,500
Total	£79,250

Transport to customers is passed on at cost.
Assume an average sale price per sq m is £42 per sq m - £115,500.

Steel

Steel is one of the most recycled materials in the world. The overall recycling rate of steel for countries such as the USA, France and the UK is somewhere between 50% and 70%. Of all industrial sectors, the construction sector is the most efficient steel recycler. The estimated recovery of steel from demolition waste in the UK is between 85% and 99%, depending on the steel product.

Structural sections are recovered from demolition waste with an estimated efficiency of 99% in the UK. Whereas steel section recycling is well established, reuse of steel sections from end-of-life buildings is neither widespread nor well documented.

Recycling reduces the energy consumption by 50%. With current high scrap values and claimed recycling rates of 99% in construction and demolition there is no room here for increasing the recycling rate and achieving environmental savings.

However, new steel in the UK has a very low recycled content because the majority of steel scrap is being exported to China. The world average for steel recycled content is reported between 40-70% but here in the UK it is much lower. Globally, the demand for new steel exceeds the available scrap for recycling. (ref. M.Samson, SCI). If the UK steel manufacturers increased their recycled content, it would reduce the eco-footprint here in the UK but globally would not make much difference (apart from the reduced shipping energy).

Total steel use in the UK is around 12.5Mt, of which 2.5Mt is used in construction. Steel waste arisings in London are around 118,000t (City Limits report) and estimated at 2.0Mt for C&DW across the UK.

Structural steel sections make up around half of the UK steel demand in construction and it is structural steel that offers the most potential for using reclaimed. Using reclaimed reduces energy consumption and environmental impact by 85-95% compared with new, depending on how much shotblasting is required to refabricate the steel.

According to the Salvo BigRec survey 1998, 76,000 tonnes of steel were salvaged for re-use in that year of which 54% were structural sections, 24% were roofing sheets, 16% were structures like staircases and 6% were complete steel frame buildings. Since 1998, the scrap value has risen considerably so steel re-use has been greatly reduced in many companies.

Advantage Steel, Summer 2004, reports how in Canada there seems to be a very similar situation with a few rare steel stockists trading in 10% reclaimed, mainly angles and tubular sections. The same barriers to widespread mainstream use of reclaimed seem to prevail. The lack of a supply chain in reclaimed material means that large mainstream orders cannot be met and the trade in reclaimed is limited to one-off sections from left-overs. The University of Toronto used 18 tons of reclaimed steel from the dismantled Royal Ontario Museum and the Eaton building in Montreal reclaimed some 30 tons to build Le Complexe les Ailes.

If all the steel sections coming out of demolished buildings that are currently being shipped abroad for recycling could be salvaged and re-used, then the construction industry could cut its embodied CO_2 by some 2Mt. Similarly, if all metal products could be reclaimed where possible, particularly sheet aluminium and also sheet steel then there is potential to reduce the industry’s embodied CO_2 by a further 2.7Mt.

Worked example

BioRegional Reclaimed are working on a proposal to dismantle two unfinished office buildings that were erected in 2001 but never completed due to the dot com crash. The owner of the buildings has two options, to demolish them and scrap the steel or to dismantle them and sell the steel on for re-use.

Option 1 - Demolish for scrap

Demolition costs	£15,000
Scrap value	£35,000
Net value	£20,000
Timescale	Demolished and site cleared in 6 weeks
Risks	Very low

Option 2 - Dismantle for re-use

Dismantling costs	£55,000
Shotblasting costs	£34,000
Haulage	£6,000
Structural certification	£3,000
Handling, storage and sales	£30,000
	£128,000
Wastage scrap value	£10,000
Resale value	£150,000
	£160,000
Net value	£32,000
Timescale	Dismantled in 10 weeks Stocks gradually cleared over 52 weeks
Risks	Damage during dismantling Unable to resell
Eco-footprint savings	420ha years
Embodied CO2 savings	581 tonnes

Results

Potential Reduction in Environmental Impact from Construction Materials

Current eco-footprint from construction materials		61.6 million ha
1) Reduce the need to build by 5%	- 3.1	= 58.5 million ha
2) Reduce over ordering by 10%	- 0.2	= 58.3 million ha
3) Re-use 75% of over ordered material	- 1.3	= 57.0 million ha
4) Reduce impact by 2% by local sourcing	- 1.1	= 55.9 million ha
5) Reduce repairs and maintenance with durable components (2%)	- 1.1	= 54.8 million ha
6) Increased renewables, energy generation efficiencies and haulage improvements of 8.2%	- 4.5	= 50.3 million ha
7) Increased efficiency / improved emissions control in processing and manufacture (10%)	- 5.0	= 45.3 million ha
8) Increased recycled content (9.5%)	- 4.3	= 41.0 million ha
9) Increased use of reclaimed materials (11.0%)	- 4.5	= 36.5 million ha
10) Choose lower impact materials (10.1%)	- 3.7	= 32.8 million ha
Total PIR	28.8 million ha	

To achieve the Factor 4 reduction of 75% would require a PIR of 46.2 million ha. Using the assumptions in this report, we achieve a 47% reduction. The measures described here require a lot of radical changes to the industry and its supply chain. To achieve the Factor 4 reduction will require even more radical changes.

However, one dimension this report does not address is over what time period these impact reductions could be achieved. Over a longer time period, perhaps the Factor 4 reduction could follow on as further improvement after the recommendations in this report have been realised.

With reference to BioRegional's Thames Gateway project, only items 2,3 and 4 and items 8, 9 and 10 could be totally controlled within the scope of the project. The other measures listed here are regional, national and even international issues or else they are the domain of other manufacturing industries.